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Dusting Versus Spraying Apple Orchards in Ohio

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DUSTING VERSUS SPRAYING APPLE ORCHARDS IN OHIO

INTRODUCTION

F. H. BALLOU AND I. P. LEWIS

In response to a special request from the organized fruit growers of Ohio the Department of Horticulture of the Ohio Experiment Station began, in the spring of 1926, a series of experiments in dusting versus spraying apple orchards for prevention of injury to foliage and fruit by fungous diseases and insect pests.

This series of dusting versus spraying experiments was carried on in eastern, central, northeastern, and southeastern Ohio. The five widely separated projects were located as follows: The Belmont County Experiment Farm, the Dale View Test Orchards (Licking County), the Mahoning County Experiment Farm, the Southeastern Experiment Farm (Meigs County), and the Washington County Experiment Farm.

The orchards in Belmont, Licking, and Washington Counties are very favorably situated in hilly sections of the State and, for the most part, occupy areas of ground of such elevation as affords unusual frost protection to buds, blossoms, and newly set fruit. No losses of fruit from cold occurred in these orchards during the full term of the experiment.

The orchard at the Mahoning County Experiment Farm occupies ground of moderate elevation, which affords fairly satisfactory cold-air drainage. In the spring of 1929 a partial loss of the apple crop was sustained by reason of freezing temperature immediately preceding the period of open blossoms. However, there was sufficient production of fruit to permit securing grades and counts in all of the variously dusted and sprayed plots.

The orchard at the Southeastern Experiment Farm, Meigs County, is not so favorably situated. It occupies the almost level summit of a low ridge running in an easterly and westerly direction. As a matter of fact, the elevation of the orchard is somewhat less than the average height of the massive hills and ridges that almost wholly surround it. Thus, a cold air pool or "frost pocket" is formed, in which nearly open fruit buds, fully expanded blossoms, or newly set apples are often partially or entirely destroyed by belated periods of cold.

THE MORE PREVALENT FUNGOUS DISEASES APPEARING DURING THE PERIOD 1926-1932

Apple scab (*Venturia inaequalis*), the more generally prevalent fungous disease to which apple foliage and fruit are subject in Ohio, was only normally troublesome in 1926, the initial season of these dusting-spraying tests. However, in 1927, 1928, and 1929, weather conditions in early spring were especially favorable for the development and dissemination of scab. In those years, this disease strikingly demonstrated its destructive possibilities in the undusted and unsprayed, or "check", plots and, likewise, in unprotected and indifferently cared-for apple orchards throughout eastern, central, and southeastern Ohio.

The disease scarcely appeared in 1930—the season of almost unprecedented drouth and heat—and gave only a little trouble in 1931. In 1932, doubtless due to unusually wet, cool weather immediately preceding and during the period of apple bloom and the consequent inability of orchard owners to make timely, thorough applications of spray, a disastrous epidemic of scab swept through the apple-producing section of northeastern Ohio. The disease was not nearly so virulent in 1932 in more southern areas of the State.

Brooks spot (*Phoma pomi*) unexpectedly appeared in midsummer, 1928, in the test orchard in Meigs County, and, as no special dust or spray treatment had been applied in anticipation of this highly destructive fungous disease, heavy losses occurred. Since the blossoms of this orchard were destroyed by frost in the seasons of 1929 and 1930, Brooks spot was not apparent, but it came again as a ruinous scourge in 1931. Its reappearance was anticipated, however, and special, additional applications of dust and spray were used.

Apple blotch (*Phyllosticta solitaria*), generally more prevalent in Ohio orchards than is Brooks spot, scarcely appeared in these test plots during the 7-year period of dusting versus spraying comparisons.

Sooty blotch (*Leptotherium pomi*), as usual, gave no trouble in our thoroughly dusted and sprayed plots, and only an occasional trace of the disease was found even on check plots of apple orchards situated on the higher elevations, as in Belmont, Licking, and Washington Counties. However, on fruit of the check plots in the Meigs County orchard (the one orchard occupying relatively low ground), sooty blotch so thickly covered the apples at harvest time that they were almost as black as if a coating of soot had been applied to them.

THE MORE DESTRUCTIVE INSECT PESTS DURING THE PERIOD 1926-1932

The codling moth (*Carpocapsa pomonella*), the lesser apple worm (*Enarmonia prunivora*), and plum curculio (*Conotrachelus nenuphar*) composed the trio of insect enemies which, while not causing really serious losses of apples in any of our test orchards—especially during the earlier years of this series of dusting-spraying experiments—,were far more prevalent than all other insect pests combined. The amount of infestation was determined on the fruit of the check, or untreated, plots left for comparison with those that were carefully dusted and sprayed.

Light infestations of trees and foliage, respectively, by San Jose scale (*Aspidiosus perniciosus*) and European red mites (*Paratetranychus pilosus*) occurred in a few of the test orchards but were cleared, in each instance, by a single, thorough application of oil emulsion just as the leaf buds were beginning to swell in very early spring.

THE EQUIPMENT USED IN DUSTING AND SPRAYING

Portable, power dusting machines of the type with built-in dust-mixing mechanism were used exclusively in this series of experiments. Invariably, at each dusting period, the tree-rows of the plots thus treated were covered from opposite directions—the dusting machine passing first along one side of the row and returning on the other side.

Because of widely differing topography of orchard land (from nearly level to extremely steep) in our several dusting-spraying projects, portable, power spraying machines of considerably varying tank capacities were for the most

part employed. In the Licking County orchard, however, a stationary spraying plant, with tank capacity of 1000 gallons and pressure readily adjustable from 300 to 500 pounds, was installed in 1929, not only with a view to rapid coverage of the orchard and all-round practical efficiency but in demonstration of the advantages of stationary spraying equipment for orchards situated on dangerously steep hill slopes.

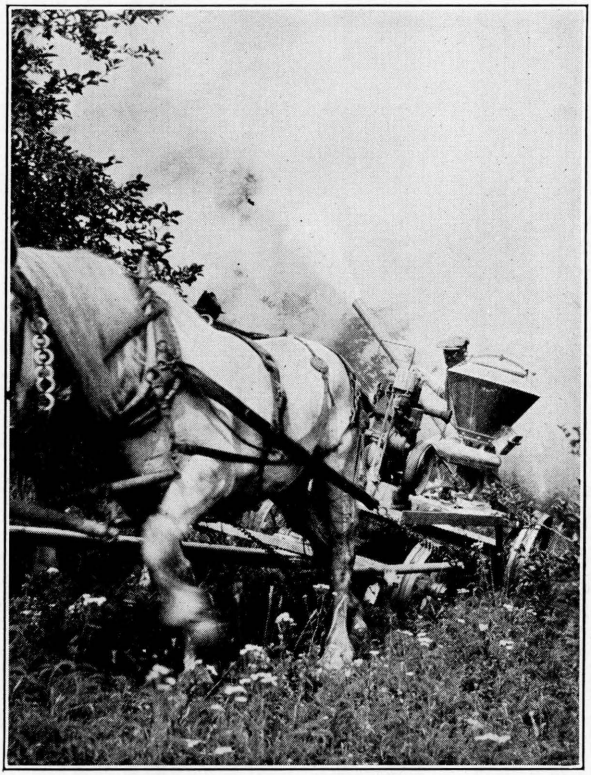

Fig. 1.—Dusting apple trees on a steep hillside at the Dale View Test Orchards in Licking County

Single-nozzle spray guns almost invariably were used, the operators working from the ground. Trees of considerable size were sprayed, first, from beneath their branches, a broad, fine, soft mist being directed upward and outward at all angles in order to cover the foliage and fruit of interior branches to the dripping point. Next, the exteriors were covered from all directions, beginning always at the topmost branches and gradually working downward with the spray by slowly sweeping the gun back and forth horizontally—not upward and downward as by far the greater number of operators are inclined to do.

MATERIALS AND FORMULAS

Five separate materials, purchased in the open market, were used in preparing the home-mixed dusts; namely, (1) pure superfine sulfur, (2) superfine dry lime-sulfur, (3) monohydrated copper sulfate, (4) superfine hydrated lime, and (5) powdered lead arsenate.

Of the many different dust formulas applied to the numerous plots composing the several test orchards in this series of experiments, less than a half dozen of the formulas were used throughout the 7-year period covered by the project. These, containing from 75 to 95 per cent of pure superfine dusting sulfur, were mixed in the orchard as needed.

Fig. 2.—Spraying apple trees at the Belmont County Experiment Farm

This picture clearly showing the "down-drift" of extremely fine mist from the main volume of forward and upward driven spray demonstrates why spraying of each tree should begin at the topmost branches and the spray-gun moved from side to side in horizontal strokes rather than upward and downward.

By taking advantage of the "down-drift" of spray partially to wet the foliage and fruit of the lower branches while the tops of the trees are being covered, much waste of spray mixture is prevented.

During the earlier years of this project 90-10 and 80-20 proportions, respectively, of superfine sulfur and hydrated lime constituted the more potent and satisfactory formulas for the prevention of apple scab. At such periods as an arsenical was necessary to protect the fruit or foliage from insects, 10 per cent of dry lead arsenate was substituted for 10 per cent of lime. Thus, the formulas given above were changed to 90-10 percentages of sulfur and lead, and 80-10-10 percentages of sulfur, lime, and lead.

In 1929, re-ground or superfine dry lime-sulfur first was used in combination with pure, superfine sulfur. This greatly refined form of dry lime-sulfur provided material promptly effective in its fungicidal action, even under abnormally low temperatures, in the prevention of infection of foliage and fruit by scab.

The plan of using dry lime-sulfur in combination with dusting sulfur in the dusting-spraying comparisons was not new. The idea was conceived by Dr. N. J. Giddings[1], pathologist of the West Virginia Experiment Station, at least 10 years previously. His "Formula No. 7" suggested using 85 per cent of dusting sulfur and 15 per cent of dry lime-sulfur, such as is commonly used for spraying or dusting orchards. However, as the ordinary dry lime-sulfur lacked the quality of extreme fineness necessary in dusting materials, it did not add to the raw, superfine sulfur with which it was combined the full measure of its potential value as a fungicide. Results were not fully satisfactory.

The original sulfur - dry lime-sulfur formula, by chance, was noted by a well known Ohio firm manufacturing spraying materials, and it was not only utilized but popularized by devising a plan whereby dry lime-sulfur could be produced in extremely refined form. Upon introduction of this new product either mixed at the factory with superfine sulfur or sulfur and lead or furnished separately for combining with these materials at the orchards, there was no change recommended or suggested by the manufacturers in the formula originally employed by Dr. Giddings—namely, 85-15 percentages, respectively, of superfine sulfur and refined dry lime-sulfur, or 75-15-10 proportions when lead arsenate was added. These formulas proved exceptionally effective and satisfactory.

In this connection it is pertinent to add that pure, raw sulfur, no matter how finely divided, under conditions of subnormal temperatures in early spring, is dangerously slow in releasing its potential fungicidal properties. Under higher temperatures, however, superfine sulfur, when thoroughly applied as a dust, doubtless is sufficiently active to render the addition of other more promptly effective elements unnecessary. Thus, it is not difficult to recognize the advantages of home-mixing of dusts. The observant orchardist may safely and successfully modify his dust or spray formulas to meet the requirements of the season. The old-time practice of using uniformly concentrated fungicidal formulas throughout the entire dusting and spraying season rapidly is being abandoned by thoughtful fruit growers—just as it deserves to be. Thus, the original 85-15 and 75-15-10 formulas of superfine sulfur and dry lime-sulfur dust were used only in the pre-blossom and petal-fall applications in the Central Ohio test orchard. The formulas for successive applications (the critical period of scab infection having passed) were modified progressively, insofar as the proportions of refined dry lime-sulfur were concerned, to the extent that only 10 per cent and, later, 5 per cent of the latter material was combined with the sulfur or sulfur and lead. In the summer dustings, high temperature prevailing, the dry lime-sulfur was omitted entirely and only superfine sulfur and lead arsenate or sulfur and lime, in proportions of 80-10-10 or 80-20, respectively, were applied.

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[1]Giddings, N. J., Anthony Berg, and E. C. Sherwood. 1927. Dusting versus spraying in the apple orchard. W. Va. Agr. Exp. Sta. Bull. 209.

A number of variously modified or "dilute" dust formulas composed of unusually low percentages of superfine sulfur and high percentages of superfine hydrated lime were tested at a number of points in Ohio at the outset of this series of dusting-spraying comparisons. Formulas of 50-50, 25-75, and 10-90 proportions, respectively, of sulfur and lime were used, with 10 per cent of lead arsenate displacing 10 per cent of lime at such times as an arsenical was necessary. These formulas were used both as full-season treatment on certain plots and, on others, only as summer applications following more concentrated and potent formulas that had been applied in the pre-blossom period. Although there was considerable evidence that reasonably modified dust formulas may be used with rather surprising results as summer applications in certain favorable seasons and on certain varieties inherently resistant to apple scab, there was, also, during the period of this test, equally impressive evidence that in unfavorable seasons, regardless of varieties, the use of greatly modified dusts is unsafe and inadvisable. It was noted that dusts containing heavy percentages of lime do not result in uniformly distributed and persisting coverage of foliage and fruit. Even with the most careful and thorough application of dusts largely abounding in lime, surprisingly little of the material could be found on the trees when the dense clouds of dust discharged from the dusting machine had passed away. It is suspected that the remarkable lack in lime dust of the properties of affinity for, and adhesiveness to, objects with which it comes in contact detracts from the naturally superior covering and adhesive qualities of sulfur when small proportions of the latter are mixed with the lime.

The number of applications of dust per season varied somewhat according to the widely differing seasons of the 7-year period. The average number per year for the five test orchards was 6.4. The maximum number was 8; the minimum number, 4. Seven dustings per season were found to fulfill practical requirements, even during seasons in which apple scab was present in the orchards to a highly destructive degree, as determined by conditions in the untreated plots of trees. These applications almost invariably were timed as follows: (1) In the bud-cluster or pre-pink stage of fruit-bud development; (2) in the pink; (3) at petal fall; (4) 1 week after petal fall; (5) 2 weeks after petal fall; (6) 3 weeks after petal fall; and (7) in mid-July, or about 10 weeks after petal fall. In this schedule lead arsenate, for control of insects, was combined with the dusts at petal fall and 2 and 10 weeks later.

Of the number of spray formulas given trial during the 7-year period, only one was employed throughout the full term—namely, the modified dry lime-sulfur - hydrated lime formulas.

These "Twin formulas", composed of 6-10-100 and 3-10-100 proportions of dry lime-sulfur, hydrated lime, and water used, respectively, for pre-bloom and post-bloom application, with 2½ pounds of dry lead arsenate added to each 100 gallons of spray at such periods as an arsenical is required, were first used at the Dale View Test Orchards in Licking County in 1922 and have been continued on the same plots of apple trees (Rome) without change for 11 consecutive years.

Several new spraying compounds were introduced by manufacturers during this dusting-spraying comparison, some of which were used for trial. A few of these new sprays proved to possess merit; but, as they became available and were used only during the closing seasons of the 7-year period of experiments, they are being continued under trial, the results to be published later.

THE PROBLEM OF VARIETIES

Conditions favorable for widely separated tests in protection of apple crops from diseases and insects are afforded only by orchards, each of which has the same few standard varieties. However, the conditions for the experiments herein reported were far from ideal. With totals of from 30 to 50 varieties of apples fruiting in each of the test farm orchards, Jonathan was the only variety growing in all of these orchards. Rome Beauty was found in sufficient numbers in all except one of the several test farm orchards. Grimes ranked third, Stayman fourth, and Delicious fifth in point of inclusion in the various trial orchards, but not in sufficiently ample numbers to render possible regional comparisons of dust and spray treatments on these well known and excellent varieties.

A better selection for dusting and spraying experiments is hardly conceivable, inasmuch as Rome and Jonathan are fairly representative, respectively, of extremes in natural or inherent susceptibility and resistance to apple scab. Jonathan, on the other hand, is extremely subject to Brooks spot, and often the fruit is seriously blemished if not wholly destroyed by it, even after careful and timely applications of approved dust and spray treatments; whereas Rome, somewhat more resistant to Brooks spot but by no means immune to this disease, responds well to proper use of suitable dusts and sprays.

Obviously, with more or less extensive groups of varieties of apples occupying the test orchards at the several experiment farms at which the experiments were conducted, various formulas of dust and spray were thoroughly applied to all except such trees as were reserved as checks. Many hundreds of generous samples of all of these varieties were taken in the seasons of apple harvest during the term of years the tests were in progress. Such samples were carefully graded, counted, and recorded. True, results of dusting and spraying these miscellaneous varieties were of practical value only when the results were combined and the average percentages of disease prevention determined on the variety groups. Only at the Mahoning County Experiment Farm orchard, however, were variety group records rather than individual variety records made necessary. In this orchard only one variety (Baldwin) occupied a place in each of the several separate test plots; Baldwin is not included in the test orchards of the other experiment farms at which dusting-spraying comparisons were conducted.

THE RULES OBSERVED IN GRADING AND CLASSIFYING THE FRUIT

The rules for grading and classifying apples, as in all previous spraying experiments conducted by the authors of this bulletin, were strictly observed throughout the 7-year term of dusting versus spraying tests.

Class No. 1—Wholly free of scab.—The apples in this class, regardless of size, are entirely free of scab. Even though no larger than a pin-head, if the tiny mark on the skin of an apple can be identified as scab, such an apple passes into Class No. 2.

Class No. 2—Very little scab.—Apples in this class may bear, on each specimen, a scab mark ranging from a mere infection point barely discernible up to a single scab ¼ inch in diameter; or two or more smaller scab marks which, in the aggregate, do not exceed ¼ inch in diameter. Fruit so nearly approaching perfect freedom from disease is eligible to U. S. Grade No. 1, provided that the other requisites as to size and color are fulfilled.

Class No. 3—Blemished by scab.—This class includes all apples having scab markings which disqualify the fruit for Class No. 2 and yet are not so seriously scabbed as to cause misshapen or deformed specimens.

Class No. 4—Deformed by scab.—This includes all apples so diseased as to be deformed or cracked.

TABLE 1.—Results of Dusting Versus Spraying Apple Orchards for Prevention of Apple Scab

At five widely separated points* in Ohio during the years 1926-1927-1928-1929-1930-1931-1932

	Dusted†					Sprayed‡				
	Wholly free of scab	Very little scab	Blemished by scab	Deformed by scab	Commercially free of scab	Wholly free of scab	Very little scab	Blemished by scab	Deformed by scab	Commercially free of scab
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Varieties: Rome Beauty in four experimental projects, and an average of a group of standard varieties in the fifth project that did not include Rome										
1926	91.2	6.2	2.3	0.1	97.4	98.8	0.7	0.4	0.0	99.5
1927	94.8	3.3	1.3	0.4	98.1	90.8	4 9	2.0	2.2	95.7
1928	77.1	16.8	4.9	0.9	93.9	83.9	12.3	3.2	0.5	96.2
1929	65.8	17.1	12.7	4.3	82.9	58.6	18.1	18.5	4.7	76.6
1930	96.5	2.6	0.8	0.0	99.1	95.4	4.0	0.5	0.0	99.4
1931	93.9	4.6	1.0	0.4	98.5	80.4	13.0	5.0	1.5	93.4
1932	76.8	13.3	6.2	3.6	90.1	88.2	3.8	4.5	3.4	92.0
7-year av.	85.1	9.1	4.1	1.3	94.2	85.1	8.1	4.8	1.7	93.3
Rome checks§—No dusting or spraying										
7-year av.	14.9	14.5	34.3	36.0	.....	.....	.....	.....	.....	.....
Variety: Jonathan in five experimental projects										
1927	99.8	0.1	0 0	0.0	99.9	99.7	0.2	0.0	0.0	99.9
1928	93.6	5.7	0.5	0.0	99.3	91.4	6.8	1.5	0.1	98.2
1929	85.1	12.4	2.1	0.2	97.6	82.3	14.9	2.3	0.3	97.2
1930	99.4	0.5	0.0	0.0	99.9	98.6	1.3	0.0	0.0	99.9
1931	98.6	1.3	0.0	0.0	99.9	97.5	2.4	0 0	0.0	99.9
5-year av.	95.3	4.0	0.5	0.0	99.3	93.9	5.1	0.7	0.1	99.0
Jonathan checks§—No dusting or spraying										
5-year av.	42.2	28.7	19.1	9.8	.....	.....	.....	.....	.....	.....

*See page 1.

†Formulas containing from 75 to 90 per cent of superfine sulfur combined either with hydrated lime or lead arsenate or both. Also, the computations give results from a number of plots dusted in 1929, 1930, 1931, and 1932 with superfine sulfur plus refined dry lime-sulfur.

‡Formulas of 6-10-100 and 3-10-100 proportions of dry lime-sulfur, hydrated lime, and water in pre-bloom and post-bloom periods, respectively, with lead arsenate added at proper periods for control of insects.

§In addition to the various scab infections, other diseases, as well as insects, rendered the entire crop unsalable.

The data appearing in Table 1 present annual, average percentages of sound and defective apples obtained by accurate grading, classification, and counting samples of fruit, from 3 to 5 bushels in each lot, from a total of 83 dusted, sprayed, and untreated lots, during the 7-year period, as follows: 37 dusted, 26 sprayed, and 20 untreated plot-lots.

SULFUR-LIME VERSUS SULFUR - LIME-SULFUR DUSTS

Table 1 presents results of 7 years' use of orchard dusts containing from 80 to 90 per cent of superfine sulfur, in comparison with simultaneous use in the same orchards of the modified dry lime-sulfur - hydrated lime spray for prevention of apple scab. At least one question remains unanswered; namely, To what extent, during the latter years of the experiment, did the addition of from 10 to 15 per cent of re-ground or superfine dry lime-sulfur increase the efficiency of dusts containing 90, 85, or 75 per cent of pure dusting sulfur? Table 2 gives a more comprehensive answer than can be offered in simple text and figures.

TABLE 2.—Comparison of Sulfur-lime and Sulfur - dry lime-sulfur Dusts for Prevention of Apple Scab

At four widely separated points in Ohio during the years 1929-1930-1931

	Dusted*		Dusted†		Sprayed‡	
	Wholly free of scab	Commercially free of scab	Wholly free of scab	Commercially free of scab	Wholly free of scab	Commercially free of scab
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Varieties (1) Rome (2) Jonathan						
1929 (1)	76.0	89.3	55.2	76.1	57.9	78.0
(2)	85.1	97.6	85.2	97.4	82.3	97.2
1930 (1)	96.5	98.6	96.6	99.9	95.4	99.4
(2)	99.4	99.9	99.3	99.9	98.7	99.9
1931 (1)	96.8	98.8	95.5	98.2	85.4	95.9
(2)	99.2	99.9	98.0	99.9	99.5	100.0
3-year average (1)	89.7	95.5	82.4	91.4	79.5	91.1
(2)	94.5	99.1	94.1	99.0	93.1	99.0
Checks (1)	26.0	But little salable or usable fruit because of infection by scab and blemishes caused by plum curculio and codling worms.				
(2)	44.7					

*Formulas containing from 75 to 90 per cent of superfine sulfur and 10 to 15 per cent of refined dry lime-sulfur, with lead arsenate at proper periods.

†Formulas containing 80 to 90 per cent of superfine sulfur, with lime or lead arsenate or both.

‡Formulas of 6-10-100 and 3-10-100 proportions of dry lime-sulfur, lime, and water in pre-bloom and post-bloom periods, with lead arsenate at proper intervals.

In presenting the data in Table 2, however, the fact should be taken into consideration that although the season of 1929 brought to Ohio orchards a seriously destructive epidemic of apple scab, the season of 1930 was one in which, due to heat and drouth, apple scab developed to a very slight extent, even in unsprayed orchards. Moreover, because of failure of scab to develop on foliage of apple trees in 1930 and recurrence of dry, hot weather during the summer and autumn of 1931, there was, again, less scab than usual. Insects, however, in both 1930 and 1931 were more numerous and troublesome than in seasons of normal temperatures and rainfall.

The data appearing in Table 2 present annual, average percentages of apples (1) wholly free and (2) commercially free of apple scab, as determined by careful grading, counting, and recording of generous tree-run samples of fruit from a total of 79 dusted, sprayed, and untreated lots, during the 3-year period, as follows: 39 dusted, 23 sprayed, and 17 untreated plot-lots.

BROOKS SPOT SERIOUSLY DESTRUCTIVE IN 1931 AND 1932 IN THE MEIGS COUNTY TEST ORCHARD

Notwithstanding the great drouth in 1930 and the fact that no apples were produced in the test orchards in Meigs County in this season on account of freezing weather late in spring, Brooks spot was destructively prevalent in these experimental orchards in 1931—more so than previously had been experienced. However, in making plans for continuation of the project of dusting versus spraying for the season of 1931, reappearance of Brooks spot had been fully anticipated and a program for protection of the fruit formulated accordingly. To what extent this program succeeded is shown in Table 3.

Authorities on dusting and spraying generally agree that, whereas sulfur-lime dusts and sprays are ineffective in prevention of Brooks spot, copper-lime applications—even in mild formulas—either in the form of dust or spray are distinctly successful in prevention of this disease. There was some evidence, it is true, in 1928 and again in 1931 that lime-sulfur sprays in such formulas as were being used to combat apple scab were helpful in slightly lessening the degree of infection of apples by Brooks spot; however, such evidence at the same time suggested that lime-sulfur formulas, even to approximate the potency of dilute copper compounds in prevention of this disease, would need to be of somewhat greater concentration than those employed in combatting scab.

The truth was again clearly demonstrated that, although the Rome apple is by no means as resistant to Brooks spot as are a number of other varieties, it quite readily responds to proper preventive measures. Both copper-lime dust and copper-lime (bordeaux) spray, applied 4 and 10 weeks after petal fall, gave almost perfect protection against this disease on the Rome variety, and with no injury to the fruit. Rome foliage was yellowed to a slight degree by the dust but not by the very dilute bordeaux spray. On the other hand, there again was demonstrated the fact that the Jonathan apple not only is exceedingly susceptible to Brooks spot but also is unresponsive to preventive measures. Moreover, Jonathan is so easily russeted, even by extremely dilute copper-lime dusts and sprays, that the advantage gained by prevention of this disease frequently is lost by serious injury to the fruit.

In the season of 1931, in the Meigs County project, use of copper-lime dust and mild bordeaux spray for prevention of Brooks spot was begun at three different intervals following petal fall; namely, 2, 3, and 4 weeks after petal fall, following the previous use of sulfur dusts and lime-sulfur spray in the regular program for prevention of apple scab. There was only slight evidence of gain in percentages of fruit wholly free of Brooks spot (an average of 3.6 per cent) by beginning the copper treatments 2 and 3 weeks after petal fall, as compared with the usual recommendation of 4 weeks after petal fall. As a matter of course, for those orchardists who make use of extremely mild bordeaux spray as the summer treatment of their apples, beginning after the petal-fall application, the menace of Brooks spot is practically and effectively provided against, and no special treatment will be necessary. Dilute bordeaux has the added advantage of being an inexpensive spray.

TABLE 3.—Dusting Versus Spraying for Prevention of Brooks Spot
In Meigs County in 1931-1932

Treatment	Variety	Wholly free of Brooks spot	Very little Brooks spot	Blemished by Brooks spot	Badly diseased by Brooks spot
		Pct.	Pct.	Pct.	Pct.
Old Rome Orchard—1931					
Average of plots dusted (8 times), others sprayed (6 times), throughout the season, with superfine sulfur and dry lime-sulfur dusting and spraying compounds	Rome	42.7	43.5	11.0	2.6
Average of separate plots on which 20-70-10 copper-lime-lead dusts and 1½-4½-2½-100 bordeaux-lead sprays were applied 4 and 10 weeks after petal fall, following use of sulfur and dry lime-sulfur dusting and spraying compounds for prevention of scab	Rome	96.2	3.4	0.0	0.0
Younger Rome and Jonathan Orchard—1931					
Average of plots dusted (8 times), others sprayed (6 times), throughout the season, with sulfur formulas, including a number of commercial sulfur dusting and spraying compounds	Rome Jonathan	3.5 2.9	15.5 16.5	25.7 14.6	55.2 65.8
Average of separate plots on which 20-70-10 copper-lime-lead dusts and 1½-4½-2½-100 bordeaux-lead sprays were applied 4 and 10 weeks after petal fall, following use of a number of commercial sulfur dusting and spraying compounds	Rome Jonathan	73.2 34.1	26.0 44.1	0.7 16.8	0.0 4.8
Check plots—1931 No dusting or spraying	Rome Jonathan	0.0 0.0	0.0 0.0	0.0 0.0	100.0 100.0
Old Rome Orchard—1932					
Average of plots dusted (8 times) as follows: 85-15 sulfur and dry lime-sulfur in pre-pink, pink, and 1 week after petal fall; 75-15-10 sulfur, dry lime-sulfur-lead at petal fall and 2 weeks later; 20-70-10 copper-lime-lead dust 3, 4, and 10 weeks after petal fall	Rome	100.0	0.0	0.0	0.0
Average of plots dusted same as above up to and including application 2 weeks after petal fall; 10-80-10 copper-lime-lead dust 3, 4, and 10 weeks after petal fall	Rome	100.0	0.0	0.0	0.0
Average of plots sprayed (6 times) as follows: 6-10-100 dry lime-sulfur and lime in pre-pink and pink; 6-10-2½-100 dry lime-sulfur, lime, and lead at petal fall, and 2, 4, and 10 weeks later	Rome	99.0	1.0	0.0	0.0
Average of plots sprayed (6 times) as follows: same as plot above up to and including application 2 weeks after petal fall; 2-10-2½-100 bordeaux-lead spray 4 and 10 weeks after petal fall	Rome	100.0	0.0	0.0	0.0
Check plot—1932 No dusting or spraying	Rome	0.0	0.0	0.0	100.0

DUSTING VERSUS SPRAYING AS RELATED TO CONTROL OF INJURIOUS INSECTS

No material difference in results during the first four seasons.—During the first 4 years of this series of tests (1926, 1927, 1928, and 1929), dusting and spraying evidently were so nearly equal in prevention of injury to the fruit by insect pests that there seemed no necessity for making extra or separate gradings and countings of apples from the many plots for the purpose of determining the very slight degrees of injury and infestation. However, the season of 1930 brought a distinct change in the situation. Conditions in early spring, followed by the almost unprecedented drouth and heat of summer and early

TABLE 4.—Average Percentages of Apples Wholly Free of Curculio and Codling Worm Blemishes (Separately Classified), Produced in Dusted, Sprayed, and Check Plots in 1930

	Treatment	Wholly free of curculio injury	Wholly free of codling worm injury	Injured by curculio	Injured by codling worms
		Pct.	*Pct.*	*Pct.*	*Pct.*
Average of 13 plots dusted, 19 plots sprayed, and 7 plots untreated, embracing 5 standard varieties and located in Mahoning, Licking, and Washington Counties in 1930	Dusted	87.9	93.3	12.1	6.7
	Sprayed	87.0	97.9	13.0	2.1
	Untreated	41.9	72.3	58.1	27.7
Average gain for dusting over spraying, in Mahoning, Licking, and Washington Counties, involving 39 separate plots, in 1930, in control of curculio				0.9 per cent	
Average gain for spraying over dusting, in the same projects, in 1930, in control of codling moth				4.6 per cent	

autumn, were particularly favorable to multiplication and highly destructive activity of insect pests. Plum curculios and codling moths, the two most prevalent of our insect enemies, presented, in their respective periods of attack, impressive examples of their harmful influence. Therefore, it became advisable to determine, as accurately as possible, at the time of apple harvest, not only to what extent these pests had invaded the experimental plots but to secure data concerning the relative efficiency of dusting and spraying in their control. This information, greatly condensed, is given in Table 4.

INSECTS SERIOUS DURING 1930 IN THE BELMONT COUNTY PROJECT

There seemed to be considerable evidence in 1930 in the Belmont County orchard that application of the exclusively employed arsenical, lead arsenate, in dust form, at the rate of 10 per cent of the total weight of dust, was less effective in control of insects than use of 2½ pounds per 100 gallons of the same material applied as a spray. As a result of this apparently important indication that dust might after all prove undependable in comparison with spray insofar as its insecticidal possibilities were concerned, it was decided to increase the proportion of lead arsenate to 15 per cent of the total weight of each lot of dust applied in the Belmont County project in 1931.

The increase in proportion of the arsenical used in dusting was made only at this single point in 1931. The percentages of injury done by insects in the year just named, in dusted plots, dropped back to comparative insignificance—the control by dusting very nearly equaling that secured by spraying. Whether this reassuring result was due to increase of arsenic in the various dusts employed or to a less favorable season for multiplication and activity of insects remains somewhat questionable.

TABLE 5.—Average Percentages of Apples Wholly Free of Insect Injuries (not Classified) Produced in Dusted, Sprayed, and Untreated Plots, 1930-1931

	Treatment	Wholly free of insect injury	More or less blemished by insects
		Pct.	*Pct.*
Average of 16 plots dusted, 16 plots sprayed, and 2 untreated, embracing two standard varieties of apples, in Belmont County, for the year 1930	Dusted	67.7	32.3
	Sprayed	81.8	18.2
	Untreated	3.5	96.5
Average gain for spraying over dusting in the Belmont County project, in 1930		14.1	
Average of 26 plots dusted, 46 plots sprayed, and 10 plots untreated, embracing 5 standard varieties in 1931. Projects located in Belmont, Licking, Mahoning, and Washington Counties	Dusted	93.3	6.7
	Sprayed	95.8	2.4
	Untreated	69.6	30.4
Average gain for spraying over dusting in Belmont, Licking, Mahoning, and Washington County projects, involving 82 separate plots, in 1931		2.5	

Insect control by dusting in Licking, Mahoning, and Washington Counties was fairly satisfactory in 1930; whereas, in the same projects in 1931, thoroughly dusted fruit wholly free of insect injury varied only from a maximum of less than 5 per cent to a minimum of less than 1 per cent below that obtained by equally careful spraying.

In Table 5 are presented not only the evidence of unusual loss of fruit by insects (injuries unclassified) in the Belmont County project in 1930 but the average results of dusting versus spraying for protection of apples from insects in 1931 in 82 separate plots located in four widely separated test orchards.

DUSTING AS A HORTICULTURAL PRACTICE WILL CONTINUE TO MEET THE REQUIREMENTS OF MANY CROP PRODUCERS

On the whole in the 7-year period, the results of dusting and spraying were remarkably similar and excellent. If dusting is discontinued in favor of spraying by orchardists who give the two methods unprejudiced trial, such discontinuance doubtless will be due to a dislike of handling and applying such materials as superfine sulfur, refined dry lime-sulfur, high-quality hydrated lime, and monohydrated copper sulfate in dry or dust form.

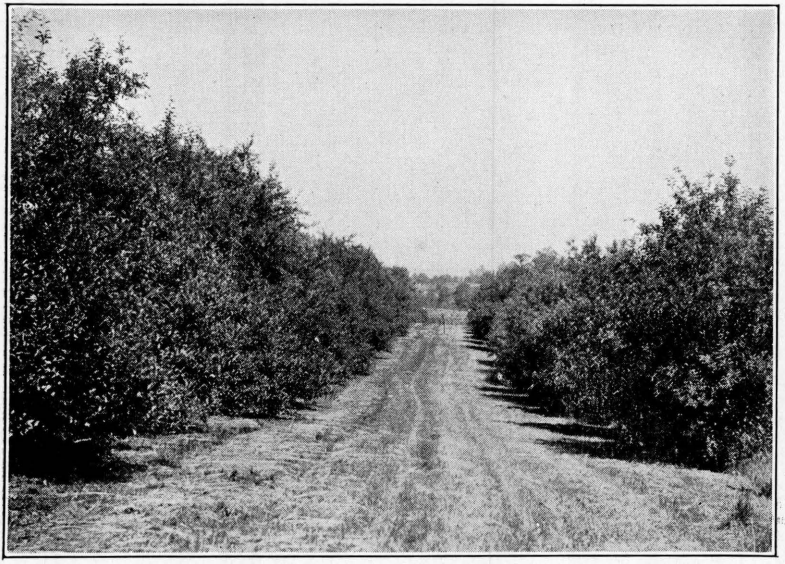

Fig. 3.—View in the test orchard at the Belmont County Experiment Farm

On the other hand, if orchard owners, after ample trial, prefer to dust rather than to spray, the preference may be due to one or more of several factors: It may be due to (1) lack of an adequate water supply for spraying; (2) the fact that rapidity of coverage of a given orchard area with a power dusting machine is far in excess of the possibilities of spraying with a power spraying outfit of moderate capacity and cost; (3) that the relatively short time required to apply dust enables the land owner to dovetail successful orcharding with other pursuits; (4) that there are fruit growers who can profitably use the dusting machine in a supplementary way, in connection with their spraying equipment; and (5) finally, that there are those who will continue to dust their orchards and other crops requiring protection from diseases and insects simply because they prefer to dust or are convinced by past experience of its splendid possibilities when properly and thoroughly done.

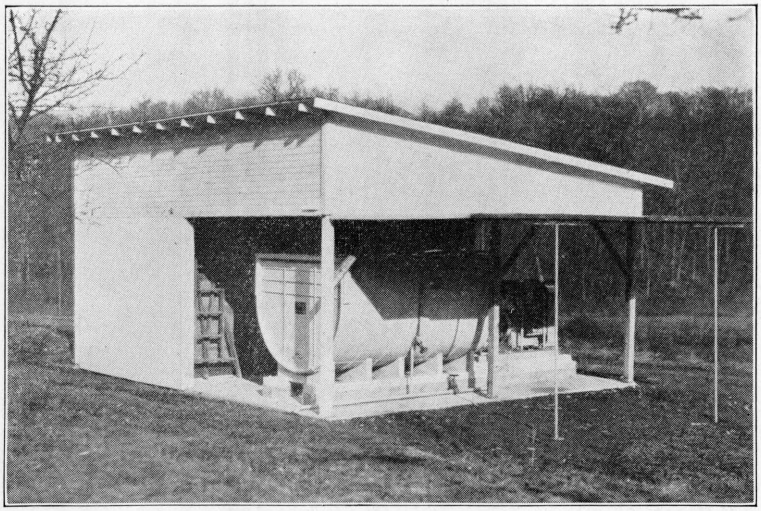

Fig. 4.—Stationary spraying plant at the Dale View Test Orchards, in Licking County

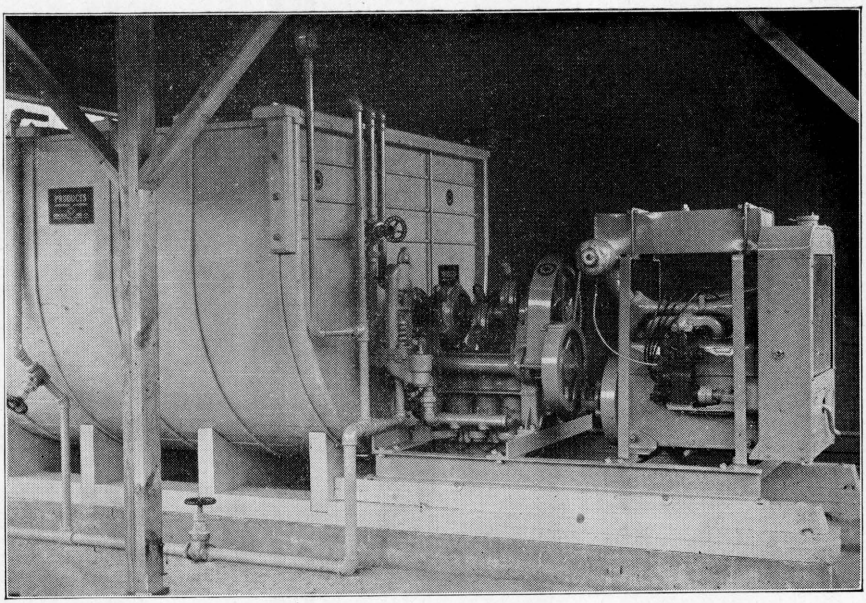

Fig. 5.—Stationary power spraying outfit at the Dale View Test Orchards, in Licking County

SUMMARY

This includes brief reference to a few of the many interesting features of the 7-year dusting versus spraying project necessarily omitted from discussion in the foregoing report.

A total of 171 test plots was under treatment, observation, and record during the 7-year term of experiments; 97 plots were dusted and 74 plots sprayed.

Treatment of this large number of plots, during the period of trial, required weighing, mixing, and applying 569 separate plot-lots of dust and 278 plot-lots of spray, 32 each of dust and spray formulas being employed in the series of tests.

While new fungicidal materials for both dusting and spraying were supplied by manufacturers or dealers desiring such materials tested in comparison with those in use from the beginning of the experiments, this bulletin necessarily has been confined almost exclusively to comparison of standard dust and spray materials and formulas that were employed from the outset to the close of the 7-year period of trial.

Throughout the series, all dusts used were compared with the modified dry lime-sulfur - hydrated lime spray which, throughout a period of 10 years, has proved safe, as well as dependable, in prevention of apple scab.

From start to finish of these experiments, thorough coverage of apple trees, at proper intervals, with dusts containing from 75 to 90 per cent of superfine sulfur gave practically the same results in scab prevention as did thorough spraying with formulas that were harmless both to foliage and fruit.

Combination of 15 per cent of refined dry lime-sulfur with pure superfine sulfur for dusting proved beneficial—especially for pre-bloom and petal-fall applications. However, there was found to be little or no advantage in continuing the addition of dry lime-sulfur at the rate of 15 per cent throughout the entire dusting period. With the coming of warmer weather in late spring and early summer, the percentage of refined dry lime-sulfur safely may be reduced to 10 and 5. In the heat of midsummer it becomes wholly unnecessary, as superfine sulfur alone is a sufficiently potent fungicide under the higher temperatures and is less likely to injure foliage or fruit.

A home-mixed combination of refined dry lime-sulfur and high-grade hydrated lime in such proportions that the dust approximated the 6-10-100 and 3-10-100 dry lime-sulfur - hydrated lime spray formulas gave good results in one test orchard and failed in others.

A commercially prepared, chemical combination of sulfur and lime to be used as a dust proved a complete failure in a season in which apple scab was destructively prevalent and difficult to hold in check. Heavy losses of apples were sustained in a number of large plots on which this mixture was used.

Copper dust used according to the usually recommended formula of 20-80 percentages, respectively, of monohydrated copper sulfate and hydrated lime, while effective both in scab and Brooks spot prevention, was found to be unsafe to use on varieties easily russeted and burned by copper. Copper-lime dust containing 10 per cent of monohydrated copper sulfate and 90 per cent of lime gave efficient control of both scab and Brooks spot and was not so injurious to foliage and fruit as the more concentrated copper compound.

Rome and Jonathan apples—the varieties predominating in this series of experiments—are fairly representative, respectively, of extremes in natural resistance and susceptibility to copper injury.

Rome is remarkably susceptible to injury by apple scab, both in fruit and foliage; whereas Jonathan is peculiarly resistant to this disease.

Jonathan is susceptible to destructive infection by Brooks spot; whereas Rome, although by no means immune to this disease, responds to timely and thorough dusting and spraying.

Brooks spot first appeared in the Meigs County orchard during a former series of spraying experiments in 1922, but only in two plots from which the sprays 2 weeks after petal fall purposely had been omitted. It did not appear again until 1928 when it did much damage to Jonathan and rather seriously attacked Rome, as no special spraying program had been formulated for protection from this disease. Brooks spot returned again with great virulence in 1931 and 1932 but was successfully combatted—especially on Rome.

Mild or dilute copper-lime sprays of 1½-4½-100 and 2-10-100 proportions of copper sulfate, lime, and water gave satisfactory protection from Brooks spot on Rome and a number of other varieties but russeted Jonathan to a greater extent than was desirable.

Extremely dilute bordeaux plus lead arsenate, used in anticipation of Brooks spot in the Washington County orchards, proved to be an almost ideal summer spray for apples, causing no injury to foliage or fruit in the hottest weather and favoring development of a smooth, glossy finish of the apples. Moreover, it is one of the least expensive sprays for midsummer use.

Dusts of lime alone or dusts in which lime is used in heavy proportion do not result in as uniform tree coverage as do sprays containing heavy percentages of lime. Notwithstanding this fact, it was found early in these dusting-spraying tests that, on varieties not subject to apple scab and in seasons not favorable for development of this disease, a relatively small proportion (about 50 per cent) of sulfur combined with approximately an equal proportion of high-grade hydrated lime, plus lead arsenate at proper intervals for use as an arsenical, gave excellent results as a summer dust, following more concentrated formulas of sulfur in the pre-bloom and petal-fall applications.

Dusting according to a spraying schedule, insofar as number and dates of application were concerned, gave practically the same results as spraying in prevention of apple scab during the latter years of the dusting-spraying comparisons at the Mahoning County Experiment Farm.

Actual requirements as to dusting and spraying schedules and formulas vary with the successive seasons and even within the same season at different points in the same section or state.

It was found that, in equally thorough dusting and spraying, 100 pounds of dust gave about the same tree coverage as 650 to 700 gallons of spray.

The average cost of dusting and spraying is practically the same—the somewhat higher cost of dusting materials being offset by the lesser time in which a given orchard area may be covered by dusting, as compared with coverage by average spraying equipment.

Dormant or delayed dormant sprays, in this series of experiments, were applied only when scale insects or European red mites were known to be present in the orchards. Sprays of oil emulsion were applied in these cases.

Stationary spraying equipment installed in the Licking County orchard project proves to be an ideal substitute for both portable sprayer and dusting machine, solving the problem of thorough treatment of orchards situated on extremely steep ground.

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